21. (New) The heat exchanger as claimed in Claim 19, wherein the projections on one opposing wall are greater in number than the projections on the other opposing wall, and the projections on the one wall are offset across the width of the tube from the projections on the other opposing wall.

22. (New) The heat exchanger as claimed in Claim 13, wherein the projections are in the form of indentations punched out from one surface of the tube to appear as projections in the internal cross-section of the tube.

23. (New) The heat exchanger as claimed in Claim 13, wherein the projections are generally square or rectangular in plan view.

24. (New) The heat exchanger as claimed in Claim 13, wherein the projections have a length greater than their width, and the length of the projections is set at an angle to the length of the tube.

25. (New) The heat exchanger as claimed in Claim 13, wherein the depth of the projections is between 35 and 50% of the internal diameter of the tube.

REMARKS

Applicant submits that by this Preliminary Amendment, Claims 1-14 have been amended. New claims 16-25 have been added. Applicant submits that no new matter has been added by way of this amendment.

Applicant is also submitting a substitute specification pursuant to 37 C.F. R. §1.121(b)(3). Applicant states that the substitute specification includes no new matter.

CONCLUSION

Applicant requests that you charge Deposit Account No. 06-1500 for any further fees which may be due. A duplicate copy of this document is enclosed for that purpose. Should the Examiner have any questions regarding this application, the Examiner is requested to call the undersigned.

Respectfully submitted,

Dated: December 5th, 2001

By: ______________________
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APPENDIX A

HEAT EXCHANGER TUBE.

TECHNICAL FIELD OF THE INVENTION

This invention relates to heat exchangers for reducing the temperature of the coolant which circulates in a heat exchange circuit. In particular the present invention relates to tubes for conveying coolant through such heat exchangers[,]. [for example vehicle radiators, or through any tube/fin heat exchanger such as a heater core.]

BACKGROUND OF THE INVENTION

US patent 4 470 452 discloses a radiator tube which is constructed so as to produce turbulence in the coolant flow to improve the heat exchange characteristics between the coolant and the air which, in use, flows through the radiator and past the tubes. In that specification the radiator tubes disclosed have flow diverting members placed along the length of each principal heat transfer surface, with the principal heat transfer surfaces being bowed outwardly. The flow diverting members (which actually take the form of indentations or dimples pressed into the walls of the tubes) are present to provide turbulence in the coolant as it flows along the tube.

US Patent 2 017 201 describes a condenser tube which has a pair of parallel walls and inwardly extending transverse indentations which form transverse restrictions in the passage through the tube offset from the central plane of the tube. The presence of these indentations or ribs produces turbulence of the liquid circulating through the tubes.

SUMMARY OF THE INVENTION

[I have now surprisingly found that] The present invention provides for a better heat exchange between the coolant and the air can be achieved by substantially reducing, or even preventing, the production of turbulence in the coolant, [whilst] while at the same time producing the necessary mixing of the coolant under laminar flow conditions. In this invention [M] mixing means that

coolant which at one moment is in contact with the tube wall moves from that position into the centre of the tube, and vice versa[,]. [t]This process is taking place continuously to encourage uniform temperature distribution throughout the coolant. In the prior art, [it was seen necessary to encourage turbulence] in order to achieve this desirable uniform temperature distribution it was important to create turbulence.

In addition to [giving] achieving good mixing of the hot coolant in the tube, the absence of turbulence in [my invention] the present invention can also reduce the back pressure which the coolant experiences [in] by flowing through the tubes. As a result, better heat transfer is achieved.

According to the invention [there is provided] a tube for conveying coolant through a heat exchanger is provided[,]. [t]The tube [having] has a flattened cross-section with two major opposing walls. [and] Further, the tube has internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube[,]. [wherein] [e]Each projection extends across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

By reducing the number of projections to this level it is possible [(in comparison to the prior art)] to reduce the resistance to coolant flow through the tube, and thus to reduce the back pressure experienced by the coolant[,]. [whilst still obtaining] At the same time, it is also possible to obtain the necessary mixing of the coolant.

The projections are preferably dimples formed in the tube walls[,]. [t]The dimples [having] have substantially equal dimensions in the direction of flow and transverse to the direction of flow. This ensures that the coolant flow is diverted in two planes, namely over the projections and around the projections, which produces particularly effective mixing of the coolant under laminar flow conditions.

Preferably, the area of the tube walls occupied by projections amounts to less than 7.5% but more than 1% of the total area of the tube walls. Better results are achieved if the area of the tube walls occupied by projections

amounts to less than 5%, and the best results are obtained [by the inventor at the time of preparation of this specification are achieved] when the area of the tube walls occupied by projections amounts to approximately 2.5% of the total area of the tube walls.

For reasons of manufacturing practicality the projections will normally be formed in a regular or repeating pattern. The projections may be arranged in groups and within each group the projections can be arranged on a line extending across the tube. The projections on one wall can extend in a diagonally opposite direction to the line of projections on the other (opposing) wall.

Considered along an imaginary line which runs parallel to the length of the tube, projections on one wall may alternate with projections on the other wall. The alternating projections may be in line or may be offset relative to an imaginary line parallel to the tube axis.

The projections on one wall can be greater in number than the projections on the other (opposing) wall.

The tube may be formed from any suitable material, for example metal or a plastics material. A preferred material is aluminium or an aluminium alloy. [and] [t]The tube is preferably formed from sheet material and is formed into a tube by a longitudinally extending weld[,]. [with] [t]The weld seam is preferably running along one edge of the tube which joins the two major walls, after the tube has been flattened. Alternatively [However], the tube could be formed by other means, for example extrusion or pre-casting, and the weld seam of the tube (if welded) could extend in other directions.

The projections preferably take the form of dimples or indentations formed in the outer surface of the tube walls, to appear as projections in the internal cross-section of the tube. The projections can be generally square in plan view, but a wide variety of non square shapes [is also] are possible. For example, the projections may have a length greater than their width[,]. [and] [i]In this case the length of the projections can be set at an angle to the length of the tube. Although it is preferred that the projections are generally square or rectangular in plan view, there may be benefits from having projections which

are oval or circular in plan view; for example circular indentations may help promote laminar flow while still permitting mixing. Oval indentations may help promote directional flow depending on the orientation of the axes.

Ends of each tube can be free from any indentations formed in the external tube surface, so that the tube ends can be reliably sealed into heat exchanger header tanks without any potential leak paths resulting from indentations lying within the [tube/] header tank joint area.

The invention also provides for a heat exchanger having a heat exchange core comprising a plurality of parallel coolant tubes separated by heat exchange fins[,]. [wherein] [e]Each of the tubes [has] have a flattened cross-section with two major opposing walls. [and] The tubes further have internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube[,]. [wherein] [e]Each of the projections extend[s] across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

In another aspect, the invention provides a method of operating a heat exchanger in which coolant is conveyed through tubes[,]. [wherein] [e]Each tube has a flattened cross-section with two major opposing walls. [and] The tubes have internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger.

The laminar flow preferably follows a path which is diverted from wall to wall and from side to side between the tube walls. This ensures excellent mixing of the coolant without disturbing the laminar nature of the flow.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a scrap view showing one part of a conventional heat exchanger construction;

Figure 2 is a cross section through a prior art heat exchanger tube;

Figure 3 is a perspective view of a tube in accordance with the invention;

Figures 4 and 5 show alternative cross-sections on the line IV,V-IV,V;

Figure 6 is a plan view of the tube of Figure 3;

Figure 7 is a plan view of part of an alternative form of tube in accordance with the invention; and

Figure[s] 8 [and 9 are] is section[s] taken on the lines VIII-VIII [and IX-IX] from Figure 3 to illustrate flow patterns in the tubes in accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In Figure 1 a typical motor vehicle radiator is shown. The radiator has a heat exchange core or matrix 10 connected to a header tank 12. The core 10 consists of a number of parallel coolant tubes 14 with heat exchange fins 16 of concertina form mounted between the tubes 14. [and] The fins 16 are in heat exchange contact with the tubes 14. In use, coolant flows into the header tank 12 and from the header tank through the tubes 14 to a similar header tank at the opposite end of the radiator. Air moves through the fins 16[, and] [t]The heat of the coolant in the tubes 14 is [given up to] exchanged with the air passing through the fins 16.

Figure 2 shows an enlarged cross sectional view through [a] tubes 14. The tubes 14 [is] are formed from thin sheet material of flattened cross-section but with slightly bowed major faces 18 and 20. The tubes 14 are formed from initially flat material which is welded together by a longitudinal weld indicated at 22. [Reference should be had to US Patent 4 470 452 in connection with the bowing of the major faces 18 and 20, which is somewhat exaggerated in Figure 2.]

The tubes 14 as shown in Figure 2 has a smooth internal bore 24. If coolant flows along [a] tubes 14 with a smooth internal bore, the coolant flow along the tubes tend[s] to be laminar or streamline flow. In this case, there will be a region at the centre of the flow (indicated [in] by the dotted lines 26 in Figure 2) where the coolant has no inducement to make contact with the walls of the tube[, and]. Therefore, this region of coolant is [therefore] insulated from the heat exchange taking place at the tube walls [by the body of coolant

between the region and the tube walls]. It is therefore clearly desirable to interfere with the coolant flow through the tube and to provide mixing of the coolant as it passes through the tubes, so that heat exchange takes place with all of the coolant, and uniform temperature distribution throughout the fluid is promoted.

The conventional approach to ensure mixing is to use so-called turbulator radiator tubes, one example of which is shown in US patent 4 470 452. Turbulator radiator tubes, as their name implies, produce turbulence in the flow which [does] enhances mixing. However the production of turbulence results in a resistance to flow which detracts from the performance.

Figure 3 is a perspective view of a tube in accordance with the invention. It is intended that coolant will flow through the tube as indicated by an arrow 28[, and whilst]. The coolant while passing through the tubes 14 will encounter projections 30a, 30b (Figures 4 and 5) which are formed on the internal wall of the tube by indentations pressed from the outside wall of the tube. The indentations are indicated by reference numeral 32 in Figure 3, and the corresponding projections by 30a and 30b in Figures 4 and 5.

Figures 4 and 5 illustrate alternative forms of indentation. In Figure 4 the indentations are round-bottomed, and in Figure 5 the indentations have a trapezoid cross-section. These sections are taken on the lines IV,V–IV,V [from] of Figure 3. The preferred depth d for the indentations 30a, 30b is between 35 and 50% of the internal tube height.

It will be noted from Figure 3 that the greater part of the surface of the tubes 14 is plain and not provided with indentations.

Although Figure 3 shows only side of the tube, the other side of the tube will also be provided with corresponding indentations 32. Figure 6 illustrates this with indentations on the upper (as seen in the Figure) face of the tube being shown in solid lines with the indentations on the lower or underneath side of the tube being shown in dotted outline. The indentations on the upper face extend along a line which makes an angle of approximately 45° to the length of the tube, and the indentations on the lower face are arranged in a corresponding manner, but along a line which makes an opposite angle of 45°

to that of the indentations on the upper face. The preferred range for such angles is 30 to 60°.

It will be noted that, in passing through the bore of the tube, the coolant flow will encounter first a projection from the lower face of the tube then a projection from the upper face then a projection from the lower face and so on. This ensures that the flow is mixed both in a direction at right angles to the major plane of the tube as well as in a transverse direction across the major plane of the tube. This is shown in Figure[s] 8 [and S] where the arrows show streamline flow around and over the projections.

Figure 7 shows a smaller section of an alternative form of tube with indentations 132 which are elongated in form and have their long axis angled to the direction of coolant flow 28. As in Figure 6, the corresponding indentations on the lower face have the same form but follow a line which crosses the line of indentations on the upper face.

The invention is not limited to any particular form or arrangement of indentations[,]. [but it is preferable that] Preferably, the indentations will be positioned in a regular array rather than a random array. The intention however is that the presence of the indentations/projections in the tube should interrupt the coolant flow sufficiently to ensure mixing of the coolant within each tube but should not interfere with the flow so drastically as to prevent the flow being generally laminar or streamline in form.

Figure 8 illustrates the nature of this flow within a tube 14 past projections 30. When the incoming laminar coolant flow is interrupted by a projection 30, the flow will divert and pass around the projection 30. However, since the distance between projections (seen in the longitudinal direction) is comparatively long, there will be sufficient time for the flow to resume its laminar form before it encounters the next projection. [whereupon diversion and therefore coolant mixing will take place again.]

Figure 8 shows the flow pattern in one plane. It must however be appreciated that the flow is also constrained by the presence of the projections both above and below the plane shown in Figure 8, and therefore the diversion of the flow when encountering a projection will take place both laterally [(as

shown in Figure 8)] and also perpendicularly [(as shown in Figure 9)] to the major plane of the tube.

The ends of each tube will preferably be formed without any indentations, so that those ends can be reliably sealed to a header plate 34 (Figure 1) where the tubes 14 communicate with the header tank 12. The fewer the indentations the lower the probability of leaks resulting from indentations coming in contact with the header joints.

In comparison with turbulator tubes as described in US patent 4 470 452, the number and area of projections which interfere with the coolant flow through the tubes is substantially reduced. This has benefits in

- increasing heat transfer between the coolant and the fins 16,
- reducing back pressure and therefore facilitating coolant flow through the tubes,
- simplifying manufacture and reducing tooling costs, and
- reducing potential leak paths between tube indentations and headers.

Typical tube dimensions for a radiator for a passenger vehicle with an internal combustion engine have a major axis dimension of about 26 mm and a minor axis dimension of about 2 mm. Each indentation 32 can have a dimension of 1-2 mm^2, and the area of the tube covered by indentations can amount to about 2.5% of the total tube surface area.

Tests can be carried out to determine the optimum configuration and form of the indentation, either through practical tests with different samples, or through computer modelling.

The foregoing discussion discloses and describes a preferred embodiment of the invention. One skilled in the art will readily recognize from such discussion, and from the accompanying drawings and claims, that changes and modifications can be made to the invention without departing from the true spirit and fair scope of the invention as defined in the following claims.

APPENDIX B

HEAT EXCHANGER TUBE

TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates to heat exchangers for reducing the temperature of the coolant which circulates in a heat exchange circuit. In particular the present invention relates to tubes for conveying coolant through such heat exchangers.

BACKGROUND OF THE INVENTION

[0002] US patent 4 470 452 discloses a radiator tube which is constructed so as to produce turbulence in the coolant flow to improve the heat exchange characteristics between the coolant and the air which, in use, flows through the radiator and past the tubes. In that specification the radiator tubes disclosed have flow diverting members placed along the length of each principal heat transfer surface, with the principal heat transfer surfaces being bowed outwardly. The flow diverting members (which actually take the form of indentations or dimples pressed into the walls of the tubes) are present to provide turbulence in the coolant as it flows along the tube.

[0003] US Patent 2 017 201 describes a condenser tube which has a pair of parallel walls and inwardly extending transverse indentations which form transverse restrictions in the passage through the tube offset from the central plane of the tube. The presence of these indentations or ribs produces turbulence of the liquid circulating through the tubes.

SUMMARY OF THE INVENTION

[0004] The present invention provides for a better heat exchange between the coolant and the air can be achieved by substantially reducing, or even preventing, the production of turbulence in the coolant, while at the same time producing the necessary mixing of the coolant under laminar flow conditions. In this invention mixing means that coolant which at one moment is in contact with the tube wall

moves from that position into the centre of the tube, and vice versa. This process is taking place continuously to encourage uniform temperature distribution throughout the coolant. In the prior art, in order to achieve this desirable uniform temperature distribution it was important to create turbulence.

[0005] In addition to achieving good mixing of the hot coolant in the tube, the absence of turbulence in the present invention can also reduce the back pressure which the coolant experiences by flowing through the tubes. As a result, better heat transfer is achieved.

[0006] According to the invention a tube for conveying coolant through a heat exchanger is provided. The tube has a flattened cross-section with two major opposing walls. Further, the tube has internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube. Each projection extends across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

[0007] By reducing the number of projections to this level it is possible to reduce the resistance to coolant flow through the tube, and thus to reduce the back pressure experienced by the coolant. At the same time, it is also possible to obtain the necessary mixing of the coolant.

[0008] The projections are preferably dimples formed in the tube walls. The dimples have substantially equal dimensions in the direction of flow and transverse to the direction of flow. This ensures that the coolant flow is diverted in two planes, namely over the projections and around the projections, which produces particularly effective mixing of the coolant under laminar flow conditions.

[0009] Preferably, the area of the tube walls occupied by projections amounts to less than 7.5% but more than 1% of the total area of the tube walls. Better results are achieved if the area of the tube walls occupied by projections amounts to less than 5%, and the best results are obtained when the area of the tube walls occupied by projections amounts to approximately 2.5% of the total area of the tube walls.

[0010] For reasons of manufacturing practicality the projections will normally be formed in a regular or repeating pattern. The projections may be arranged in groups and within each group the projections can be arranged on a line extending

across the tube. The projections on one wall can extend in a diagonally opposite direction to the line of projections on the other (opposing) wall.

[0011] Considered along an imaginary line which runs parallel to the length of the tube, projections on one wall may alternate with projections on the other wall. The alternating projections may be in line or may be offset relative to an imaginary line parallel to the tube axis.

[0012] The projections on one wall can be greater in number than the projections on the other (opposing) wall.

[0013] The tube may be formed from any suitable material, for example metal or a plastics material. A preferred material is aluminium or an aluminium alloy. The tube is preferably formed from sheet material and is formed into a tube by a longitudinally extending weld. The weld seam is preferably running along one edge of the tube which joins the two major walls, after the tube has been flattened. Alternatively, the tube could be formed by other means, for example extrusion or pre-casting, and the weld seam of the tube (if welded) could extend in other directions.

[0014] The projections preferably take the form of dimples or indentations formed in the outer surface of the tube walls, to appear as projections in the internal cross-section of the tube. The projections can be generally square in plan view, but a wide variety of non square shapes are possible. For example, the projections may have a length greater than their width. In this case the length of the projections can be set at an angle to the length of the tube. Although it is preferred that the projections are generally square or rectangular in plan view, there may be benefits from having projections which are oval or circular in plan view; for example circular indentations may help promote laminar flow while still permitting mixing. Oval indentations may help promote directional flow depending on the orientation of the axes.

[0015] Ends of each tube can be free from any indentations formed in the external tube surface, so that the tube ends can be reliably sealed into heat exchanger header tanks without any potential leak paths resulting from indentations lying within the header tank joint area.

[0016] The invention also provides for a heat exchanger having a heat exchange core comprising a plurality of parallel coolant tubes separated by heat exchange fins. Each of the tubes have a flattened cross-section with two major opposing walls. The tubes further have internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube. Each of the projections extend across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

[0017] In another aspect, the invention provides a method of operating a heat exchanger in which coolant is conveyed through tubes. Each tube has a flattened cross-section with two major opposing walls. The tubes have internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger.

[0018] The laminar flow preferably follows a path which is diverted from wall to wall and from side to side between the tube walls. This ensures excellent mixing of the coolant without disturbing the laminar nature of the flow.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:

[0020] Figure 1 is a scrap view showing one part of a conventional heat exchanger construction;

[0021] Figure 2 is a cross section through a prior art heat exchanger tube;

[0022] Figure 3 is a perspective view of a tube in accordance with the invention;

[0023] Figures 4 and 5 show alternative cross-sections on the line IV,V-IV,V;

[0024] Figure 6 is a plan view of the tube of Figure 3;

[0025] Figure 7 is a plan view of part of an alternative form of tube in accordance with the invention; and

[0026] Figure 8 is section taken on the lines VIII-VIII from Figure 3 to illustrate flow patterns in the tubes in accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] In Figure 1 a typical motor vehicle radiator is shown. The radiator has a heat exchange core or matrix 10 connected to a header tank 12. The core 10 consists of a number of parallel coolant tubes 14 with heat exchange fins 16 of concertina form mounted between the tubes 14. The fins 16 are in heat exchange contact with the tubes 14. In use, coolant flows into the header tank 12 and from the header tank through the tubes 14 to a similar header tank at the opposite end of the radiator. Air moves through the fins 16. The heat of the coolant in the tubes 14 is exchanged with the air passing through the fins 16.

[0028] Figure 2 shows an enlarged cross sectional view through tubes 14. The tubes 14 are formed from thin sheet material of flattened cross-section but with slightly bowed major faces 18 and 20. The tubes 14 are formed from initially flat material which is welded together by a longitudinal weld indicated at 22.

[0029] The tubes 14 as shown in Figure 2 has a smooth internal bore 24. If coolant flows along tubes 14 with a smooth internal bore, the coolant flow along the tubes tend to be laminar or streamline flow. In this case, there will be a region at the centre of the flow (indicated by the dotted lines 26 in Figure 2) where the coolant has no inducement to make contact with the walls of the tube. Therefore, this region of coolant is insulated from the heat exchange taking place at the tube walls. It is therefore clearly desirable to interfere with the coolant flow through the tube and to provide mixing of the coolant as it passes through the tubes, so that heat exchange takes place with all of the coolant, and uniform temperature distribution throughout the fluid is promoted.

[0030] The conventional approach to ensure mixing is to use so-called turbulator radiator tubes, one example of which is shown in US patent 4 470 452. Turbulator radiator tubes, as their name implies, produce turbulence in the flow which enhances mixing. However the production of turbulence results in a resistance to flow which detracts from the performance.

[0031] Figure 3 is a perspective view of a tube in accordance with the invention. It is intended that coolant will flow through the tube as indicated by an arrow 28. The coolant while passing through the tubes 14 encounter projections 30a,

30b (Figures 4 and 5) which are formed on the internal wall of the tube by indentations pressed from the outside wall of the tube. The indentations are indicated by reference numeral 32 in Figure 3, and the corresponding projections by 30a and 30b in Figures 4 and 5.

[0032] Figures 4 and 5 illustrate alternative forms of indentation. In Figure 4 the indentations are round-bottomed, and in Figure 5 the indentations have a trapezoid cross-section. These sections are taken on the lines IV,V–IV,V of Figure 3. The preferred depth d for the indentations 30a, 30b is between 35 and 50% of the internal tube height.

[0033] It will be noted from Figure 3 that the greater part of the surface of the tubes 14 is plain and not provided with indentations.

[0034] Although Figure 3 shows only side of the tube, the other side of the tube will also be provided with corresponding indentations 32. Figure 6 illustrates this with indentations on the upper (as seen in the Figure) face of the tube being shown in solid lines with the indentations on the lower or underneath side of the tube being shown in dotted outline. The indentations on the upper face extend along a line which makes an angle of approximately 45° to the length of the tube, and the indentations on the lower face are arranged in a corresponding manner, but along a line which makes an opposite angle of 45° to that of the indentations on the upper face. The preferred range for such angles is 30 to 60°.

[0035] It will be noted that, in passing through the bore of the tube, the coolant flow will encounter first a projection from the lower face of the tube then a projection from the upper face then a projection from the lower face and so on. This ensures that the flow is mixed both in a direction at right angles to the major plane of the tube as well as in a transverse direction across the major plane of the tube. This is shown in Figure 8 where the arrows show streamline flow around and over the projections.

[0036] Figure 7 shows a smaller section of an alternative form of tube with indentations 132 which are elongated in form and have their long axis angled to the direction of coolant flow 28. As in Figure 6, the corresponding indentations on the lower face have the same form but follow a line which crosses the line of indentations on the upper face.

[0037] The invention is not limited to any particular form or arrangement of indentations. Preferably, the indentations will be positioned in a regular array rather than a random array. The intention however is that the presence of the indentations/projections in the tube should interrupt the coolant flow sufficiently to ensure mixing of the coolant within each tube but should not interfere with the flow so drastically as to prevent the flow being generally laminar or streamline in form.

[0038] Figure 8 illustrates the nature of this flow within a tube 14 past projections 30. When the incoming laminar coolant flow is interrupted by a projection 30, the flow will divert and pass around the projection 30. However, since the distance between projections (seen in the longitudinal direction) is comparatively long, there will be sufficient time for the flow to resume its laminar form before it encounters the next projection.

[0039] Figure 8 shows the flow pattern in one plane. It must however be appreciated that the flow is also constrained by the presence of the projections both above and below the plane shown in Figure 8, and therefore the diversion of the flow when encountering a projection will take place both laterally and also perpendicularly to the major plane of the tube.

[0040] The ends of each tube will preferably be formed without any indentations, so that those ends can be reliably sealed to a header plate 34 (Figure 1) where the tubes 14 communicate with the header tank 12. The fewer the indentations the lower the probability of leaks resulting from indentations coming in contact with the header joints.

[0041] In comparison with turbulator tubes as described in US patent 4 470 452, the number and area of projections which interfere with the coolant flow through the tubes is substantially reduced. This has benefits in

- increasing heat transfer between the coolant and the fins 16,
- reducing back pressure and therefore facilitating coolant flow through the tubes,
- simplifying manufacture and reducing tooling costs, and
- reducing potential leak paths between tube indentations and headers.

[0042] Typical tube dimensions for a radiator for a passenger vehicle with an internal combustion engine have a major axis dimension of about 26 mm and a

minor axis dimension of about 2 mm. Each indentation 32 can have a dimension of 1-2 mm^2, and the area of the tube covered by indentations can amount to about 2.5% of the total tube surface area.

[0043] Tests can be carried out to determine the optimum configuration and form of the indentation, either through practical tests with different samples, or through computer modelling.

[0044] The foregoing discussion discloses and describes a preferred embodiment of the invention. One skilled in the art will readily recognize from such discussion, and from the accompanying drawings and claims, that changes and modifications can be made to the invention without departing from the true spirit and fair scope of the invention as defined in the following claims.

10/009504
JC Rec'd PCT/PTO 05 DEC 2001

Appendix C

In the Claims:

1. (Amended) A tube [(14)] for conveying coolant through a heat exchanger [(10)], the tube having a flattened cross-section with two major opposing walls comprising: an [and] internal projections [(30)] on the two major opposing walls [(18,20)], the projections extending into [the] an internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, [characterised in] such that each projection [(30)] extends across less than 30% of the width of the tube and [the] an area of the tube walls [(18,20)] having projections amounts to less than 7.5% of [the] a total area of the tube walls.

2. (Amended) [A] The tube as claimed in Claim 1, wherein the area of the [tube] walls [(18,20)] having projections amounts to less than 7.5% of the total area of the tube walls and more than 1% of the total area of the tube walls.

3. (Amended) [A] The tube as claimed in Claim 1 [or Claim 2], wherein the area of the tube walls [(18,20)] having projections amounts to less than 5% of the total area of the tube walls.

4. (Amended) [A] The tube as claimed in Claim 1, [or Claim 2] wherein the area of the tube walls [(18,20)] having projections amounts to approximately 2.5% of the total area of the tube walls.

5. (Amended) [A] The tube as claimed in Claim 1 [any preceding claim], wherein the projections [(30)] are in the form of dimples [(32)] formed in the tube walls [(18,20)], the dimples having substantially equal dimensions in the direction of coolant flow and transverse to the direction of flow.

6. (Amended) [A] The tube as claimed in Claim 1 [any preceding claim], wherein the projections [(30)] are arranged in groups and within each group, the projections are arranged on a line extending diagonally across the tube.

7. (Amended) [A] The tube as claimed in Claim 6, wherein the line of projections [(30)] on one opposing wall [(18)] extends in a diagonally opposite direction to the line of projections [(30)] on the other opposing wall [(20)].

8. (Amended) [A] The tube as claimed in Claim 6 [or Claim 7], wherein the projections [(30)] on one opposing wall [(18)] are greater in number than the projections on the other opposing wall [(20)], and the projections on the one wall [(18)] are offset across the width of the tube from the projections on the other opposing wall [(20)].

9. (Amended) [A] The tube as claimed in Claim 1 [any preceding claim], wherein the projections [(30)] are in the form of indentations [(32)] punched out from one surface of the tube to appear as projections in the internal cross-section of the tube.

10. (Amended) [A] The tube as claimed in Claim 1 [any preceding claim], wherein the projections [(30)] are generally square or rectangular in plan view.

11. (Amended) [A] The tube as claimed in Claim 1 any preceding claim, wherein the projections [(30)] have a length greater than their width, and the length of the projections is set at an angle to the length of the tube.

12. (Amended) [A] The tube as claimed in Claim 1 [any one of the preceding claims], wherein the depth of the projections [(30)] is between 35 and 50% of the internal diameter of the tube.

13. (Amended) A heat exchanger having a heat exchange core [(10)] comprising:

a plurality of parallel coolant tubes; [(14) separated by]

heat exchange fins [(16),] separating the coolant tubes;

wherein each of the tubes [(14)] has a flattened cross-section with two major opposing walls [(18,20)]; and

internal projections [(30)] on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, [characterised in] such that each projection [(30)] extends across less than 30% of the width of the tube [(14)] and [the] an area of the tube walls having projections amounts to less than 7.5% of [the] a total area of the tube walls.

14. (Amended) A method of operating a heat exchanger in which coolant is conveyed through tubes [(14)], wherein each tube [(14)] has a flattened cross-section with two major opposing walls [(18,20)] and internal projections [(30)] on the major opposing walls, characterised in that the projections [(30)] extend into the internal cross-sectional area of the tube [(14)] to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger, and wherein the laminar flow follows a path which is diverted from wall to wall and from side to side between the tube walls.[.]

Add new claims 16-25 as follows:

16. (New) The heat exchanger as claimed in Claim 13, wherein the area of the tube walls having projections amounts to less than 5% of the total area of the tube walls.

17. (New) The heat exchanger as claimed in Claim 13, wherein the area of the tube walls having projections amounts to approximately 2.5% of the total area of the tube walls.

18. (New) The heat exchanger as claimed in Claim 13, wherein the projections are in the form of dimples formed in the tube walls, the dimples having substantially equal dimensions in the direction of coolant flow and transverse to the direction of flow.

19. (New) The heat exchanger as claimed in Claim 13, wherein the projections are arranged in groups and within each group, the projections are arranged on a line extending diagonally across the tube.

20. (New) The heat exchanger as claimed in Claim 19, wherein the line of projections on one opposing wall extends in a diagonally opposite direction to the line of projections on the other opposing wall.

21. (New) The heat exchanger as claimed in Claim 19, wherein the projections on one opposing wall are greater in number than the projections on the other opposing wall, and the projections on the one wall are offset across the width of the tube from the projections on the other opposing wall.

22. (New) The heat exchanger as claimed in Claim 13, wherein the projections are in the form of indentations punched out from one surface of the tube to appear as projections in the internal cross-section of the tube.

23. (New) The heat exchanger as claimed in Claim 13, wherein the projections are generally square or rectangular in plan view.

24. (New) The heat exchanger as claimed in Claim 13, wherein the projections have a length greater than their width, and the length of the projections is set at an angle to the length of the tube.

25. (New) The heat exchanger as claimed in Claim 13, wherein the depth of the projections is between 35 and 50% of the internal diameter of the tube.